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Activities and Catch Composition of Artisanal Elasmobranch Fishing Sites on the Eastern Coast of Baja California Sur, Mexico

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Abstract.—Eighty–three artisanal fishing sites were documented from seasonal surveys of the Gulf of California coast of Baja California Sur conducted during El Niño (1998) and La Niña (1999) conditions. The direct targeting of elasmobranchs was observed at approximately half (48.2%) of these sites. Sharks numerically dominated sampled landings (71.3%, n = 693), and exceeded those of batoids during all seasons. Among the primary species in observed landings were the scalloped hammerhead, *Sphyrna lewini* (15.2%, n =148), Pacific angel shark, *Squatina californica* (11.6%, n = 113), blue shark, *Prionace glauca* (11.4%, n = 111), Pacific sharpnose shark, *Rhizoprionodon longurio* (11.3%, n = 110), and pygmy devil ray, *Mobula munkiana* (8.6%, n = 84).

Increasing concern regarding the status and sustainability of elasmobranch populations in Mexican waters has prompted the development of a federal management plan and underscored the need for fundamental information on targeted species (DOF 2007). Improved management of Mexican elasmobranch fisheries has been hampered, in part, by a lack of detailed quantitative information on the location and activities of artisanal fishing sites, species composition of landings, and basic life history information of targeted species (Castillo–Geniz et al. 1998; Márquez–Farías 2002). This type of data has recently been provided for two of the four states bordering on the Gulf of California (Sonora, Bizzarro et al. 2009; Baja California, Smith et al. 2009), one of Mexico's most important regions in terms of elasmobranch and overall fisheries production (CONAPESCA 2003). However, similar information from Baja California Sur is lacking.

Elasmobranchs landings averaged 2.9% of total fishery production in Baja California Sur during 1998–2003, the most recent available time series. Total landings during this period ranged from 3628–5459 t (CONAPESCA 2003). Elasmobranch landings from Baja California Sur comprised 12.1% of national production during 2003 and averaged 12.8% of national production during 1998–2003. Sharks, especially "tiburón" (sharks > 1.5 m total length), comprised the majority of reported landings, with rays contributing an average of 26.3% by weight during 1998–2003 (CONAPESCA 2003).

To improve the understanding, conservation, and management of exploited shark and ray populations in the western Gulf of California (GOC), a two–year study was undertaken during 1998–1999 to describe the extent and activities of the Baja California Sur artisanal elasmobranch fishery. Specific objectives of this project were to: 1) determine the locations and activities of elasmobranch fishing sites in Baja California Sur; 2) determine species composition of elasmobranchs from these sites, and 3) provide baseline biological information (size composition, sex ratio, reproductive status) for the primary species in landings.

Study Site Information

Bordered by the Pacific Ocean to the west and south and the GOC to the east (Figure 1), mainland Baja California Sur contains 2,705 km^2 of coastline, the most of any Mexican state (INEGI 2007). Thirteen major offshore islands occur off the central and southern GOC coast of Baja California Sur (Lindsay 1983). Coastal and insular shelves and terraces are absent or diminished in most regions of coastal Baja California Sur, with the notable exception of Bahía Concepción and Bahía La Paz. Outside these regions, the shelf is generally rocky and narrow (~ 5–10 km), with a sharp shelf break at approximately 200 m (Maluf 1983). Within and adjacent to these embayments, the coastal regions are composed primarily of sandy substrates. Extremely deep water (> 1000 m) occurs within 20 km off the southeastern part of the state (Dauphin and Ness 1991). The only river on the Baja California Peninsula, the Rio Santa Rosalía, flows into the GOC at the town of Mulege, creating estuarine conditions.

Baja California Sur is one of Mexico's most important states in terms of fishery production, accounting for 10.9% of landings and 5.4% of revenues according to the latest available data (CONAPESCA 2003). These totals ranked third and seventh, respectively, among Mexican states. The most important fishery resources in Baja California Sur were, in order of descending landings during 1998–2003: sardines, squids, and tunas (CONAPESCA 2003). In addition, Baja California Sur is the main source of abalone, clam, and lobster production. The primary fishery ports in Baja California Sur are Puerto San Carlos, on the Pacific coast, and La Paz, Loreto, and Santa Rosalía on the GOC coast.

Materials and Methods

Seasonal surveys of artisanal fishing sites located in Baja California Sur were conducted during 1998–1999, a time period that included both El Niño and La Niña oceanographic conditions (Schwing et al., 2002). Data were collected specifically from January 9–February 21, March 23–May 16, September 9–November 15, 1998, and January 15–February 25, March 3–May 15, June 2–29, September 11–November 13, 1999. Time spent at each camp was typically less than one day and most camps were visited sporadically within and among seasons. Seasons were defined as follows: spring (March–May), summer (June–August), autumn (September–November), and winter (December–February).

Locations of fishing sites were determined from maps, local knowledge of fishing activity, and exploration. Once located, the exact position of each site was determined with a handheld Global Positioning System unit. At each site, artisanal fishing vessels ("pangas"), typically 5.5–7.6 m long, open–hulled fiberglass boats with outboard motors of 55–115 hp, were sampled and fishermen were interviewed to determine fishery targets, elasmobranch species composition, fishing locations, gear types, ex–vessel prices, and markets. All references to mesh size of gillnets indicate stretched mesh size (the distance between knots when the mesh is pulled taut). Type of fishing site (A = little to no

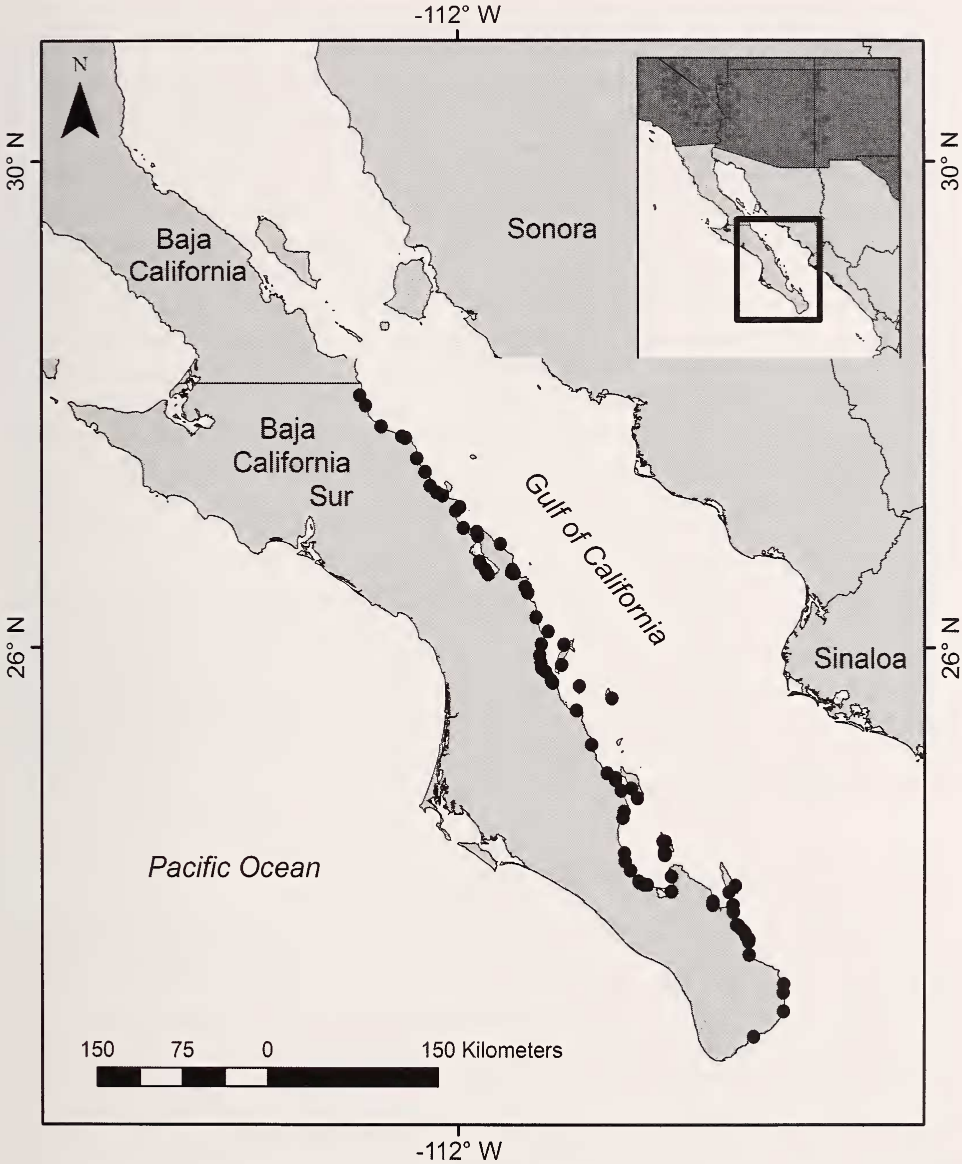

Fig. 1. Study site of Baja California Sur in northwestern Mexico. Artisanal fishing camp locations are depicted with black dots.

infrastructure, B = moderate infrastructure, C = significant infrastructure), permanence (1 = permanent, 2 = seasonal), period of activity, and number of active pangas were recorded for each site.

Elasmobranch landings were identified to lowest possible taxonomic level, enumerated, sexed, and measured whenever possible. Gymnurid rays (i.e., *Gymnura crebripunctata*, *G. marmorata*) and sharks of the genus *Mustelus* (i.e., *M. albipinnis*, *M. californicus*, *M. dorsalis*, *M. lunulatus*) were grouped into species complexes (i.e., *Gymnura* spp., *Mustelus* spp.) because of taxonomic confusion within these genera during the time of surveys.

Taxonomic problems involving these groups have since been resolved (Castro–Aguirre et al. 2005; Smith et al. in press). Standard measurements (e.g., stretched total length, disc width) were consistently recorded on linear axes to the nearest 1.0 cm for sampled sharks and rays whenever possible. Disc width was recorded for skates (Rajidae), but converted to total length using the relationships estimated by Castillo–Géniz (2007).

All measured specimens were utilized to determine size composition and sex ratio of landings. For all species with ≥ 50 measured individuals, potential differences in the size composition of landed females and males were examined using parametric and non–parametric approaches, as appropriate. Raw size data were first evaluated for normality and equality of variances using Shapiro–Wilk and two–tailed variance ratio (*F*) tests, respectively (Zar 1999). When data were determined to be normally distributed and of equal variance, two–tailed *t*–tests were applied to test the hypothesis that mean sizes of females and males did not significantly differ ($\alpha = 0.05$) among landings. Size data that did not meet these assumptions were transformed (log, square root) and re–examined with Shapiro Wilk and two–tailed *F*–tests. If transformations were unsuccessful, size data were evaluated using two–tailed non–parametric Mann–Whitney *U* tests (Zar 1999). Additionally, the assumption of equal sex ratios (1:1) within the landings was tested using chi–square analysis with Yates correction for continuity (Zar 1999).

Reproductive status was assessed for males and females and specimens were classified as either mature or immature. Males with fully calcified claspers that could be easily rotated, coiled epididymides, and differentiated testes were considered mature (Pratt 1979; Ebert 2005). Female maturity was determined by macroscopic inspection of the ovaries and uteri (Martin and Cailliet 1988; Ebert 2005). Mature females had oviducal glands that were well–differentiated from the uteri, and vitellogenic follicles generally >1.0 cm diameter and/or egg capsules in utero.

Results

Fishing Sites and General Fishery Characteristics

A total of 83 artisanal fishing sites, broadly termed "camps," was documented in Baja California Sur during 85 survey days in 1998–99 (Table 1). However, directed elasmobranch fishing effort was observed at only 48.2% of these locations ($n = 40$). The remaining sites either did not target elasmobranchs ($n = 9$) or directed elasmobranch fishing efforts could not be determined ($n = 34$) at the time of the survey. Most fishing camps were active throughout the year (66.3%, $n = 55$). However, 15 camps were found to be occupied seasonally (18.1%) and the period of use could not be determined for 13 additional camps (15.7%). Fishing camps with little to no infrastructure were common in BCS (45.8%, $n = 38$). Lacking electricity or sources for water, fishermen from nearby towns or cities (e.g. La Paz, Loreto) lived at and fished from such camps for extended periods. Fishing camps were typically established in remote locations, including islands (e.g., BCS–45, BCS–46). Thirty (36.1%) of the surveyed sites contained moderate infrastructure. Artisanal fishing activities were also observed in association with cities or larger towns (e.g., BCS–20, BCS–71, BCS–77). The number of active pangas ranged from one at several camps to approximately 450 at BCS–77, and varied seasonally. Camps or landing sites that exclusively targeted elasmobranchs were rarely observed. Fishing sites were principally nearshore for small coastal sharks and rays, and offshore (to distances of 60 km) for large pelagic sharks.

Artisanal fisheries identified along the eastern coast of Baja California Sur were diverse and highly opportunistic. Activities, targets, and gear use changed seasonally within

Table 1. Descriptive information for all artisanal fishing camps documented in Baja California Sur (BCS) during 1998-1999. Type = A (little to no infrastructure), B (moderate infrastructure), and C (significant infrastructure); Perm. (Permanence) = 1 (permanent) and 2 (seasonal); Active = period of fishing activity; #Pangas = number or range of operational artisanal fishing vessels at the time of survey(s); Elasmo. (elasmobranchs targeted) = Yes (elasmobranchs were targeted during the year) and No (there was no directed fishery for elasmobranchs). Zero values listed for #Pangas indicate that the camp was temporarily inactive (because of weather, holidays, etc.) or seasonally abandoned at the time of survey. In all instances, U = unknown.

Camp Code	Camp Name	Latitude	Longitude	Type	Perm.	Active	#Pangas	Elasmo.
BCS-01	La Playa	23.054	-109.671	C	1	Year-Round	11-171	No
BCS-02	La Playa II	23.247	-109.437	A	2	Oct-Feb	2	U
BCS-03	Los Frailes	23.389	-109.439	A	2	Sep-Apr	17-80	Yes
BCS-04	La Ribera	23.454	-109.433	B	1	Year-Round	13-50	No
BCS-05	Los Barriles	23.675	-109.707	C	1	Year-Round	0-80	No
BCS-06	Las Pilitas	23.771	-109.710	A	2	Nov-Jun	1	Yes
BCS-07	Punta Pescadero	23.791	-109.708	A	1	Year-Round	4-5	U
BCS-08	La Tina	23.817	-109.730	B	1	Year-Round	1-4	U
BCS-09	San Javier (Los Algodones)	23.832	-109.736	B	1	Year-Round	1-2	Yes
BCS-10	El Cardonal	23.843	-109.743	B	2	6 Months	3-5	Yes
BCS-11	La Linea	23.866	-109.766	B	1	Year-Round	1	U
BCS-12	San Isidro	23.894	-109.789	B	1	Year-Round	1-4	Yes
BCS-13	Boca del Alamo	23.901	-109.805	B	1	Year-Round	6-12	Yes
BCS-14	Ensenada de Los Muertos	23.997	-109.831	B	1	Year-Round	3	Yes
BCS-15	Punta Arenas	24.051	-109.834	B	1	Year-Round	3-40	Yes
BCS-16	La Ventana	24.051	-109.992	B	1	Year-Round	7-8	Yes
BCS-17	El Sargento	24.079	-109.992	U	1	Year-Round	11-150	U
BCS-18	Canechica	24.149	-109.864	A	2	Nov-Jun	3	Yes
BCS-19	La Loberita	24.197	-109.815	A	1	Year-Round	2	Yes
BCS-20	La Paz	24.152	-110.317	C	1	Year-Round	8-20	Yes
BCS-21	El Quelele	24.203	-110.508	A	1	Year-Round	1	U
BCS-22	Los Rodriguez	24.205	-110.536	B	1	Year-Round	3	U
BCS-23	Punta Leon	24.218	-110.566	A	1	Year-Round	1-2	Yes
BCS-24	Las Pacas	24.228	-110.577	B	1	Year-Round	4-6	U
BCS-25	Pichilingue	24.267	-110.317	B	2	U	11	U
BCS-26	El Sauzoso	24.311	-110.641	U	1	Year-Round	3	No
BCS-27	San Juan de la Costa	24.381	-110.683	A	1	Year-Round	2-4	Yes
BCS-28	La Cueva de San Gabriel	24.427	-110.370	A	1	Year-Round	1	U
BCS-29	El Saladito	24.443	-110.688	U	U	U	0-2	Yes
BCS-30	El Empachado	24.446	-110.374	A	1	Year-Round	1	U
BCS-31	La Cueva Cropola	24.447	-110.367	B	1	Year-Round	2	Yes
BCS-32	La Partida	24.531	-110.368	B	1	Year-Round	10	U
BCS-33	La Cueva (La Partida)	24.532	-110.383	B	1	Year-Round	U	U
BCS-34	Punta Coyote	24.710	-110.700	A	2	8 Months	2	No
BCS-35	El Portugues	24.757	-110.690	A	2	Sep-Apr	2-3	Yes
BCS-36	El Pardito	24.858	-110.586	A	1	Year-Round	4-5	Yes
BCS-37	San Evaristo	24.915	-110.714	B	1	Year-Round	9-20	Yes
BCS-38	La Palma Sola	24.933	-110.633	B	2	6 Months	6	U
BCS-39	Nopolo	24.995	-110.758	A	1	Year-Round	7	U
BCS-40	La Curva de Punta Alta	25.009	-110.759	A	1	Year-Round	3	U
BCS-41	Punta Alta	25.012	-110.759	U	1	Year-Round	5-6	No
BCS-42	Los Burros	25.049	-110.825	A	1	Year-Round	2	U

fishing camps and a diverse variety of organisms including teleosts, squids, and shrimps were often targeted from vessels in the same camp. An influx of fishermen, particularly from the state of Chiapas, immigrated to some camps in Baja California Sur to target large sharks and pelagic rays during summer and autumn. Elasmobranchs landed in remote locations were typically filleted, salted, and dried as a method of preservation and sold for local (Baja California Sur) consumption. Elasmobranchs were also directly consumed within fishing camps and were partially relied upon as a component of subsistence fisheries. Buyers often traveled to select camps to purchase salted or fresh elasmobranchs directly from the fishermen. Typical ex–vessel prices were similar for

Table 1. continued.

Camp Code	Camp Name	Latitude	Longitude	Type	Perm.	Active	#Pangas	Elasmo.
BCS-43	Timbabichi	25.264	-110.947	A	1	Year-Round	5	No
BCS-44	Agua Verde	25.522	-111.068	B	1	Year-Round	4-10	Yes
BCS-45	Isla Catalina, Punta Sur	25.613	-110.788	A	2	Jul-Apr	0	U
BCS-46	Isla Monserrat	25.707	-111.044	A	U	U	U	U
BCS-47	Ensenada Blanca	25.732	-111.255	B	1	Year-Round	5-13	Yes
BCS-48	Ligui	25.749	-111.266	B	1	Year-Round	0-9	No
BCS-49	Puerto Escondido	25.818	-111.312	C	2	U	0	U
BCS-50	Juncalito	25.843	-111.341	B	1	Year-Round	2-15	Yes
BCS-51	Ensenada Amarilla-Rincon	25.867	-111.183	A	2	5 Months	2	U
BCS-52	Col. Zaragoza	25.883	-111.347	C	1	Year-Round	9	U
BCS-53	Nopolo II	25.939	-111.358	C	1	Year-Round	0	U
BCS-54	Loreto	26.024	-111.343	C	1	Year-Round	25-200	Yes
BCS-55	Puerto Balandra	26.022	-111.164	A	2	11 Months	0-5	Yes
BCS-56	Ensenadita	26.121	-111.290	A	2	U	2	Yes
BCS-57	San Bruno	26.226	-111.386	B	1	Year-Round	0-125	U
BCS-58	San Juanico	26.414	-111.450	B	2	3 Months	8	Yes
BCS-59	Palo San Juan	26.457	-111.472	U	U	U	3	U
BCS-60	El Manglito	26.553	-111.764	A	2	4-6 Months	2-6	Yes
BCS-61	San Nicolas	26.559	-111.557	B	1	Year-Round	2-14	Yes
BCS-62	El Sauce	26.558	-111.567	A	1	Year-Round	2-3	Yes
BCS-63	El Cardancito	26.566	-111.577	A	1	Year-Round	7	Yes
BCS-64	La Huertita	26.589	-111.786	U	1	Year-Round	1-5	Yes
BCS-65	La Ramadita	26.586	-111.573	B	1	Year-Round	7-16	Yes
BCS-66	Requeson	26.635	-111.826	A	2	U	2-5	U
BCS-67	El Frijol	26.650	-111.831	A	2	3 Months	5	U
BCS-68	Santa Rosa	26.783	-111.667	A	1	Year-Round	2	U
BCS-69	Guadalupe	26.843	-111.844	A	2	U	2	Yes
BCS-70	Los Hornitos	26.874	-111.851	A	1	Year-Round	U	U
BCS-71	Mulege	26.903	-111.959	C	1	Year-Round	4-80	Yes
BCS-72	Cooperativa de los Del Real	27.033	-112.017	A	2	6 Months	5	U
BCS-73	Punta Coloradito	27.060	-111.986	A	1	Year-Round	3	No
BCS-74	San Rafaelito	27.149	-112.123	A	2	U	0-6	U
BCS-75	San Bruno (2)	27.173	-112.169	B	1	Year-Round	10-50	Yes
BCS-76	San Lucas	27.223	-112.220	B	1	Year-Round	4-120	Yes
BCS-77	Santa Rosalia	27.328	-112.259	C	1	Year-Round	8-450	Yes
BCS-78	Santa Maria	27.429	-112.326	B	1	Year-Round	0-15	Yes
BCS-79	Punta la Reforma	27.583	-112.414	A	U	U	0	U
BCS-80	La Reforma	27.595	-112.444	A	U	U	0	U
BCS-81	Santana	27.673	-112.608	B	1	Year-Round	4-8	Yes
BCS-82	La Trinidad	27.829	-112.729	A	2	U	0	U
BCS-83	Mojon	27.905	-112.775	A	2	U	0	Yes

teleosts and large sharks ($10–$20(MX)/kg). However, small sharks and rays were sold for considerably lower prices (≤ $5(MX)/kg). Overall, markets for elasmobranchs were primarily associated with Baja California and Baja California Sur cities (e.g., Ensenada, La Paz, Loreto, Los Cabos), but also included Mexico City and the US. Skins and jaws of some sharks (e.g., silky shark, *Carcharhinus falciformis*) were occasionally retained and sold. At sites with more infrastructure, sharks and rays were typically dressed and sold fresh to local buyers or cooperatives.

Among the 96 sampled vessels for which gear type and set (e.g., bottom, surface) details were available, bottom set gillnets were found to be the most common fishing method (38.5%) with surface set longlines observed only slightly less frequently (31.3%). However, a diverse range of gear was employed among the sampled vessels. Bottom set

Table 2. Seasonal and total catch composition of shark, skate, and ray landings sampled from artisanal vessels targeting elasmobranchs in Baja California Sur during 1998-1999. Number of vessels sampled per season = Spring (n = 74), Summer (n = 8), Autumn (n = 21), and Winter (n = 28). n = number of individuals, % = percentage of elasmobranch landings. No survey was conducted during summer 1998.

		Spring		Summer		Autumn		Winter		Total	
Higher Taxon	Lowest Possible Taxon	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Shark	*Alopias pelagicus*	4	0.9	7	6.7	0	0.0	0	0.0	11	1.1
	Alopias superciliosus	2	0.5	0	0.0	0	0.0	0	0.0	2	0.2
	Carcharhinidae	0	0.0	0	0.0	0	0.0	1	0.4	1	0.1
	Carcharhinus falciformis	9	2.1	0	0.0	25	12.6	2	0.8	36	3.7
	Carcharhinus galapagensis	0	0.0	0	0.0	1	0.5	0	0.0	1	0.1
	Carcharhinus limbatus	6	1.4	8	7.6	0	0.0	4	1.7	18	1.9
	Carcharhinus longimanus	2	0.5	0	0.0	0	0.0	0	0.0	2	0.2
	Carcharhinus obscurus	2	0.5	0	0.0	0	0.0	0	0.0	2	0.2
	Carcharhinus porosus	0	0.0	0	0.0	1	0.5	0	0.0	1	0.1
	Echinorhinus cookei	1	0.2	0	0.0	0	0.0	0	0.0	1	0.1
	Galeocerdo cuvier	1	0.2	0	0.0	1	0.5	0	0.0	2	0.2
	Isurus oxyrinchus	25	5.9	0	0.0	0	0.0	13	5.4	38	3.9
	Mustelus spp.	14	3.3	0	0.0	5	2.5	5	2.1	24	2.5
	Nasolamia velox	0	0.0	57	54.3	0	0.0	0	0.0	57	5.9
	Negaprion brevirostris	0	0.0	0	0.0	3	1.5	0	0.0	3	0.3
	Prionace glauca	83	19.4	3	2.9	1	0.5	24	9.9	111	11.4
	Rhizoprionodon longurio	103	24.1	0	0.0	6	3.0	1	0.4	110	11.3
	Sphyrna lewini	21	4.9	0	0.0	56	28.3	71	29.3	148	15.2
	Sphyrna zygaena	10	2.3	0	0.0	2	1.0	0	0.0	12	1.2
	Squatina californica	25	5.9	0	0.0	64	32.3	24	9.9	113	11.6
	Subtotal	**308**	**72.1**	**75**	**71.4**	**165**	**83.3**	**145**	**59.9**	**693**	**71.3**
Skate	*Raja velezi*	0	0.0	0	0.0	0	0.0	2	0.8	2	0.2
	Subtotal	**0**	**0.0**	**0**	**0.0**	**0**	**0.0**	**2**	**0.8**	**2**	**0.2**
Ray											
	Dasyatis dipterura	8	1.9	2	1.9	2	1.0	21	8.7	33	3.4
	Dasyatis longa	14	3.3	1	1.0	1	0.5	4	1.7	20	2.1
	Gymnura spp.	0	0.0	0	0.0	0	0.0	33	13.6	33	3.4
	Manta birostris	1	0.2	0	0.0	0	0.0	0	0.0	1	0.1
	Mobula japanica	22	5.2	4	3.8	0	0.0	3	1.2	29	3.0
	Mobula munkiana	65	15.2	3	2.9	0	0.0	16	6.6	84	8.6
	Mobula spp.	1	0.2	0	0.0	2	1.0	0	0.0	3	0.3
	Mobula thurstoni	0	0.0	0	0.0	0	0.0	6	2.5	6	0.6
	Myliobatis californica	0	0.0	0	0.0	2	1.0	1	0.4	3	0.3
	Myliobatis longirostris	1	0.2	0	0.0	0	0.0	6	2.5	7	0.7
	Narcine entemedor	2	0.5	0	0.0	0	0.0	1	0.4	3	0.3
	Pteroplatytrygon violacea	0	0.0	0	0.0	1	0.5	0	0.0	1	0.1
	Rhinobatos glaucostigma	0	0.0	0	0.0	7	3.5	0	0.0	7	0.7
	Rhinobatos leucorhynchus	0	0.0	0	0.0	1	0.5	0	0.0	1	0.1
	Rhinobatos productus	2	0.5	16	15.2	1	0.5	0	0.0	19	2.0
	Rhinobatos spp.	0	0.0	0	0.0	9	4.5	0	0.0	9	0.9
	Rhinoptera steindachneri	0	0.0	0	0.0	7	3.5	1	0.4	8	0.8
	Urobatis halleri	1	0.2	0	0.0	0	0.0	0	0.0	1	0.1
	Urobatis maculatus	2	0.5	0	0.0	0	0.0	0	0.0	2	0.2
	Zapteryx exasperata	0	0.0	0	0.0	0	0.0	3	1.2	3	0.3
	Subtotal	**119**	**27.9**	**26**	**24.8**	**33**	**16.7**	**95**	**39.3**	**273**	**28.1**
Batoid	Unidentified	0	0.0	4	3.8	0	0.0	0.0	0.0	4	0.4
	Subtotal	**0**	**0.0**	**4**	**3.8**	**0**	**0.0**	**0.0**	**0.0**	**4**	**0.4**
	Total	**427**	**100.0**	**105**	**100.0**	**198**	**100.0**	**242**	**100.0**	**972**	**100.0**

longlines (2.1%), vertically set longlines (18.8%), surface set gillnets (7.8%), and gillnets set in the water column (2.1%) were also used to target elasmobranchs. Gear was typically soaked for 24 hours before retrieval. Vessels often set two or more nets and occasionally used mixed gear types, such as traps and bottomset gillnets, during the same fishing trip. Handlines were often used as a secondary gear to target multiple species, including small sharks and occasionally rays. Crews usually consisted of two individuals, but groups of 3 and 4 were also observed.

During 1998–1999, 972 specimens were recorded from directed elasmobranch fishery landings in Baja California Sur, corresponding to at least 19 shark, 1 skate, and 18 ray species (Table 2). The majority of the documented specimens were sharks (71.3%). The scalloped hammerhead, *Sphyrna lewini*, was the most frequently observed species (15.2%). However, three other species were similarly represented within the overall catch composition, the: blue shark, *Prionace glauca* (11.4%), Pacific sharpnose shark, *Rhizoprionodon longurio* (11.3%), and Pacific angelshark, *Squatina californica* (11.6%). Rays contributed 28.1% of the sampled landings and skates (i.e., rasptail skate, *Raja* *velezi*) represented a minor component of the overall catch (0.2%). The pygmy devilray, *Mobula munkiana*, was the most commonly recorded batoid, comprising 8.6% of the total landings.

Although the principal species varied, sharks numerically dominated landings during all seasons. The relative proportion of shark landings was least during winter (59.9%) and greatest during autumn (83.3%). *Rhizoprionodon longurio* (24.1%), *P. glauca* (19.4%), and *M. munkiana* were the primary species landed during spring. Among the limited number of winter landings, more than half the observed specimens were whitenose shark, *Nasolamia velox* (54.3%). Autumn landings were dominated by three shark species, *S. californica* (32.3%) *S. lewini* (28.3%), and *C. falciformis* (12.6%). *Sphyrna lewini* (29.3%) specimens comprised the greatest proportion of observed winter landings, with butterfly rays, *Gymnura* spp., *S. californica*, *P. glauca*, and the diamond stingray, *Dasyatis dipterura*, of comparable lesser abundance (8.7–13.6%).

Fishing effort was often opportunistic and directed toward multiple teleost and/or elasmobranch taxa. At least 20 species and 10 higher taxa of teleosts were recorded opportunistically from artisanal elasmobranch landings. Mackerels (Scombridae, $n = 4$) and sea basses (Serranidae, $n = 4$) were the most speciose teleost families in landings. Finescale triggerfish (*Balistes polylepis*) were frequently taken in association with demersal ray species and *S. californica* during all seasons, and were occasionally targeted using handlines after gillnets were set or retrieved. Billfishes (Istiophoridae) and dolphinfish (*Coryphaena hippurus*) were noted among landings from pelagic gillnet and longline fisheries.

Biological Information

A total of 56 *N. velox* was directly examined from artisanal fishery landings (Table 3, Figure 2a). The smallest and largest specimens were females, ranging from 66–121 cm stretched total length (STL). Average male size (82.1 ± 9.6 cm STL) was significantly less than that of females (92.4 ± 13.4 cm STL) ($t = 3.292$, $P = 0.002$). The number of females ($n = 29$) and males ($n = 27$) recorded from the landings did not depart significantly from a predicted sex ratio of 1:1 ($\chi^2_{0.05,1} = 0.018$, $P = 0.897$). The majority of inspected male specimens were juveniles (69–100 cm STL, $n = 26$), but adults of 91 cm STL and 105 cm STL were documented. Female maturity was not assessed for this species.

Sampled landings of *P. glauca* were dominated by males, representing 73.9% of the total (Table 3, Figure 2b). Specimens ranged from 133–275 cm STL, and average size of males (199.1 ± 22.5 cm STL) and females (201.7 ± 23.0 cm STL) was similar within the landings ($t = 0.4901$, $P = 0.625$). The observed sex ratio indicated a significant departure from a 1:1 relationship ($\chi^2_{0.05,1} = 20.098$, $P < 0.001$). Ten adult female *P. glauca* measuring 197–230 cm STL were assessed for maturity during February and early March of 1999. All were adults, with nine gravid individuals carrying 3–30 (17.9 ± 11.9 embryos/individual) embryos of 8–41 cm STL (29.3 ± 7.1 cm STL). A juvenile male of 153 cm STL was documented, but all those ≥ 158 cm STL were mature ($n = 44$).

A limited size range of *S. lewini* was recorded among fishery landings, with catches consisting primarily of relatively small individuals (Table 3, Figure 2c). The 84 examined specimens ranged from 77–114 cm STL. The majority of sampled specimens were < 95 cm STL. Mean female (88.1 ± 5.4 cm STL) and male (88.8 ± 5.6 cm STL) sizes did not differ significantly ($t = 1.66$, $P = 0.671$). Likewise, the proportion of sexes was not significantly different from a 1:1 ratio ($\chi^2_{0.05,1} = 0.964$, $P = 0.353$). All inspected male (77–97 cm STL, $n = 50$) and female (81–114 cm STL, $n = 47$) individuals were juveniles.

Table 3. Size composition of elasmobranchs sampled from artisanal fishery landings in Baja California Sur during 1998-1999. Only specimens identified to species are included. DW = disc width; PCL = precaudal length; STL = stretched total length; TL = total length; TL* = estimated total length.

Elasmobranch Group	Species	Sex	n	Measurement (cm)	Minimum	Maximum	Mean	±1 SD
Shark	*Carcharhinus falciformis*	F	19	PCL	122	162	144.2	11.3
		M	16	PCL	95	189	140.5	20.8
	Isurus oxyrinchus	F	17	STL	110	268	166.4	40.1
		M	17	STL	92	253	178.6	44.0
	Nasolamia velox	F	29	STL	66	121	92.4	13.4
		M	27	STL	69	105	82.1	9.6
	Negaprion brevirostris	F	3	STL	119	128	122.3	4.9
	Prionace glauca	F	24	STL	141	230	201.7	23.0
		M	68	STL	133	275	199.1	22.5
	Rhizoprionodon longurio	F	26	STL	69	118	105.2	14.7
		M	19	STL	65	110	95.0	13.8
	Sphyrna lewini	F	37	STL	77	97	88.1	5.4
		M	47	STL	81	114	88.8	5.6
	Sphyrna zygaena	F	4	STL	204	262	242.8	18.5
		M	1	STL	224	224		
	Squatina californica	F	36	TL	62	93	77.2	5.9
		M	31	TL	68	89	77.5	5.5
Batoid	*Dasyatis dipterura*	F	7	DW	41	94	57.3	21.2
		M	6	DW	46	58	49.7	4.4
	Dasyatis longa	F	6	DW	50	118	76.8	31.2
		M	9	DW	57	96	77.0	12.2
	Pteroplatytrygon violacea	F	1	DW	67	67		
	Mobula japanica	F	13	DW	132	233	189.8	35.3
		M	8	DW	132	306	209.0	47.9
	Mobula munkiana	F	20	DW	62	107	86.5	16.6
		M	37	DW	64	108	91.9	14.1
	Mobula thurstoni	F	4	DW	93	170	122.8	34.7
		M	2	DW	102	156	129.0	38.2
	Narcine entemedor	F	4	STL	56	74	63.5	8.2
	Raja velezi	F	2	DW	62	66	64.0	2.8
	Raja velezi	F	2	TL*	80	85	82.7	3.1

The 36 female and 31 male *S. californica* examined from Baja California Sur artisanal fishery landings ranged from 62–93 cm total length (TL), with females representing the largest and smallest specimens (Table 3, Figure 2d). Mean sizes of female (77.2 ± 5.9 cm TL) and male (77.5 ± 5.5 cm TL) individuals did not differ significantly ($t = -0.199$, $P = 0.843$). No significant difference was detected in the proportion of females to males ($\chi^2_{0.05,1} = 0.239$, $P = 0.653$). Adult females of 85 cm TL and 93 cm TL were observed, and a 86 cm TL female landed during January, 1998 contained 5 embryos. Juvenile females of 77–86 cm TL were also noted. Among males, adults measured 69–89 cm TL ($n = 7$), whereas juveniles ranged from 68–79 cm TL ($n = 4$).

A broad size range of *M. munkiana* (62–108 cm DW) was observed among fishery landings (Table 3, Figure 3). The average size of males (91.9 ± 14.1 cm DW) was larger but did not significantly differ from that of females (86.5 ± 16.6 cm DW) ($t = -1.305$, $P = 0.197$). Males of 100–105 cm DW comprised the most common size class. The ratio of females ($n = 20$) to males ($n = 37$) differed significantly from a predicted sex ratio of 1:1 ($\chi^2_{0.05,1} = 4.491$, $P = 0.036$).

Discussion

More than half (56.5%) of all artisanal fishing sites documented in the Gulf of California during 1998–1999 were located in Baja California Sur (Bizzarro et al. 2007a).

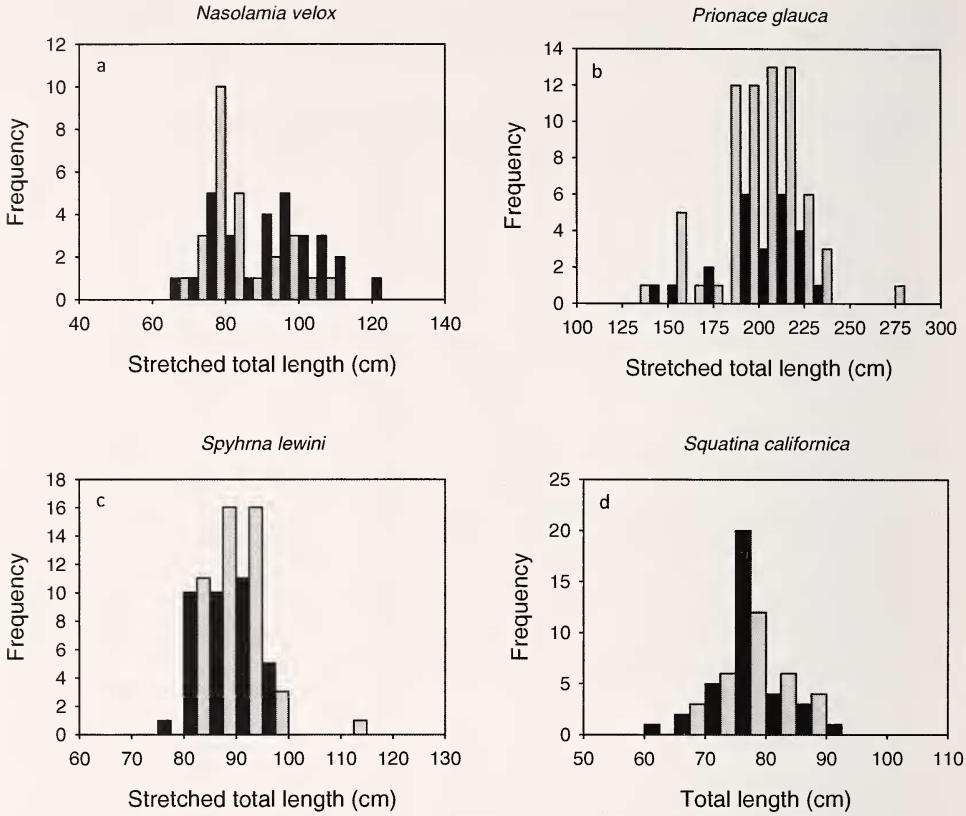

Fig. 2. Size compositions of the primary shark species sampled from artisanal fishery landings in Baja California Sur during 1998–1999: (**a**) female (n = 29) and male (n = 27) whitenose sharks, *Nasolamia velox*, (**b**) female (n = 24) and male (n = 68) blue sharks, *Prionace glauca*, (**c**) female (n = 37) and male (n = 47) scalloped hammerheads, *Sphyrna lewini*, and (**d**) female (n = 36) and male (n = 31) Pacific angel sharks, *Squatina californica*. Females are depicted in black, males in grey.

Directed elasmobranch fishing activities were extensive, but artisanal fisheries were diverse and highly opportunistic. Therefore, sites in eastern Baja California Sur that exclusively targeted elasmobranchs were scarce. In addition, survey efforts were insufficient to adequately document the activities of many artisanal fishing sites. Sharks numerically dominated sampled landings during all seasons, and were primarily represented by similar proportions of large (e.g, *P. glauca*; *I. oxyrinchus*) and small (*R. longurio*, *S. californica*) species. *Mobula munkiana* was the most abundant ray in overall Baja California Sur landings. Large sharks were fished using drift gillnets and assorted longline gear, whereas small demersal sharks and rays were typically fished with bottom set gillnets and longlines.

Teleosts (e.g., Lutjanidae, Serranidae) were the primary targets at most camps, with invertebrates (e.g., squids, Teuthoidea) also commonly targeted. Both teleosts and squids were typically fished with handlines. In addition, many fishermen switched from artisanal fishing to sportfishing periodically, especially in tourist areas. Elasmobranch fishing efforts were greatest for large sharks during summer and autumn among surveyed camps. Rays and small sharks (especially *S. californica*) were fished throughout the year in a relatively small proportion of surveyed camps, with rays targeted more often during

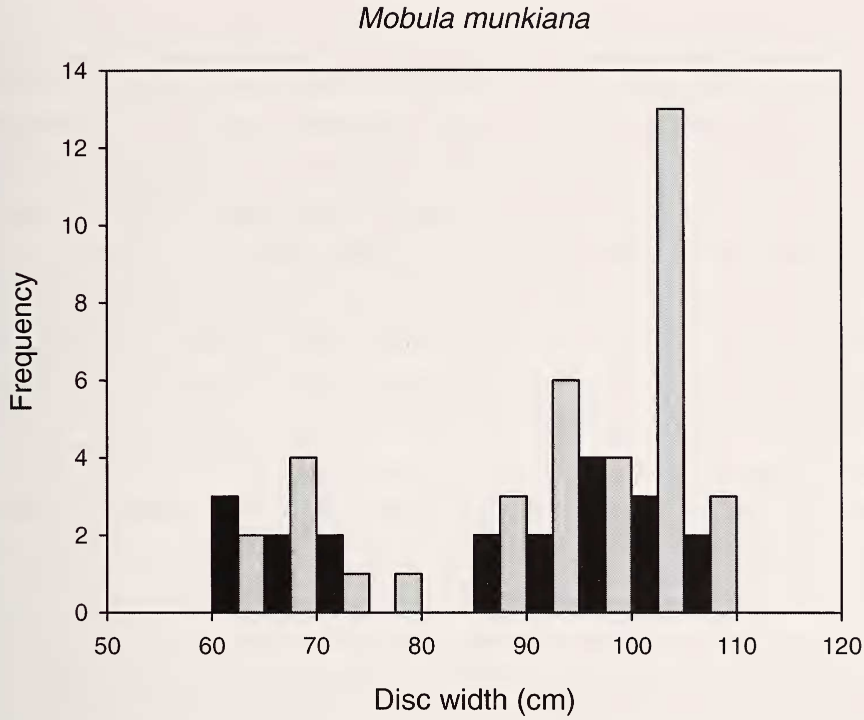

Fig. 3. Size compositions of female (black, $n = 20$) and male (grey, $n = 37$) Munk's devil rays sampled from artisanal fishery landings in Baja California Sur during 1998–1999.

summer and small sharks more often during autumn–spring. The capture of squids (especially *Dosidicus gigas*), a primary commercial fishery in Baja California Sur during the course of this study, was widely noted using handlines during summer and autumn 1999. Artisanal fisheries for sardines or tunas, however, were not observed (CONAPESCA 2003). Because relatively few camps were visited during each season and time spent at each camp was typically less than one day, the extent and activities of artisanal fishing operations in Baja California Sur may not be entirely representative of the actual conditions at the time of survey.

In addition to being artisanal fishery targets, elasmobranchs are common bycatch in the industrial drift net fishery for swordfish (*Xiphias gladius*) and purse seine fishery for yellowfin tuna (*Thunnus albacares*) (Mendizábal–Oriza et al. 2000). Both of these pelagic fisheries are substantial in Baja California Sur (CONAPESCA 2003). Rays have also been reported as common bycatch in industrial shrimp fisheries off the Gulf of California coast of Baja California Sur (Fitch and Schultz 1978). Sportfishing is a major industry in Baja California Sur and also represents a considerable source of mortality for large sharks in this region (Castillo–Géniz 1992).

Field efforts were conducted during winter, spring, and autumn of 1998 and during all seasons of 1999. However, sample sizes were probably insufficient to substantiate species composition during all seasons with the possible exception of spring. The total number of pangas targeting elasmobranchs could not be reliably obtained for Baja California Sur because only a small subset of active camps were visited each season, camps were only visited for a brief period of time, and the total number of vessels targeting elasmobranchs was not consistently recorded at each camp. It is also likely that, because directed elasmobranch fisheries were documented at 82% of adequately surveyed sites, elasmobranch fishing effort may also be extensive among the 34 insufficiently surveyed sites. Based on available data, the greatest elasmobranch effort (n = 23 vessels) was recorded during winter from a large shark fishery (e.g., *I. oxyrinchus*) at Punta Arenas (BCS–15). The greatest overall artisanal fishing effort witnessed in Baja California Sur during this study was directed at squid (*D. gigas*) during September 1999, with 570 vessels participating in the fishery from BCS–76 (n = 120) and BCS–77 (n = 450).

Detailed aspects of some elasmobranch fisheries in Baja California Sur are available for comparison with the results of this study. The artisanal shark fishery in Baja California Sur was summarized by Villavicencio–Garayzar (1996a), but specific camp locations were not provided. Several fishing sites targeting mobulids in the region of Bahía de La Paz, however, have been documented (BCS–14 to BCS–17, BCS–21, BCS–36, BCS–37) (Notarbartolo–di–Sciara 1987; 1988; Villavicencio–Garayzar 1991). Mobulid fisheries were noted at BCS–15 during spring, BCS–35 during spring and summer, and BCS–36 during winter of this survey. Additionally, on June 21, 2001, 12 pangas were observed targeting mobulids (especially *M. munkiana*) with 10–12" drift gillnets or harpoons at Punta Arenas (BCS–15) (Bizzarro unpub.). An active fishery at San Ignacio lagoon was previously confirmed, but not described (Villavicencio–Garayzar and Abitia–Cárdenas 1994; Villavicencio–Garayzar 1996b). An angel shark (*S. californica*) fishery was previously documented at Agua Verde (BCS–44; Villavicencio–Garayzar 1996b) and remained active, at least during winter months, of 1998–1999. Other elasmobranch fishing sites were previously reported from the mainland or islands associated with Bahía de La Paz, most of which were inactive or not documented during this study (Klimley and Nelson 1981; Mariano–Meléndez and Villavicencio–Garayzar 1998). Artisanal fisheries for elasmobranchs have also been reported from the Pacific coast of Baja California Sur, with large sharks (e.g., *C. falciformis*, *P. glauca*, *I. oxyrinchus*) targeted at Las Barranchas, Punta Belcher, and Punta Lobos (Hoyos–Padilla 2003; Ribot–Carballal et al. 2005) and rays targeted at Puerto Viejo and other camps in Bahía Almejas (Villavicencio–Garayzar 1995; Bizzarro et al. 2007b; Smith et al. 2007).

Because rather few specimens were sampled in Baja California Sur, reliable inferences regarding the fauna of this region are limited. Overall, species richness was equivalent between sharks and batoids and diversity was considerable, with 38 species documented. Sampling was conducted during highly variable interannual oceanic conditions (Schwing et al. 2002), which probably served to accentuate typical regional elasmobranch diversity. The elasmobranch fauna observed in landings was more tropical in origin than those of either Baja California (Smith et al. 2009) or Sonora (Bizzarro et al. 2009). It also contained a comparatively greater number of oceanic species (e.g., pelagic stingray, *Pteroplatytrygon violacea*, oceanic whitetip shark, *C. longimanus*) and large coastal and pelagic sharks.

Although an equal number of shark and ray species were documented, sharks were far more important to the fishery. This observation was supported by official fishery statistics, as sharks constituted 73.7% of reported landings during 1998–2003 (CONAPESCA 2003), and was in contrast to the situation documented in Baja California (Smith et al. 2009) or Sonora (Bizzarro et al. 2009). Seasonal migrations of large pelagic sharks to the waters off southern Baja California Sur have historically supported substantial fisheries and may be one of the primary reasons for this trend (Villavicencio–Garayzar 1996a). The coastal geography of Baja California Sur may also not be ideal for the establishment of ray fisheries. Fisheries for rays are typically centered in embayments and other insular waters, where rays tend to aggregate for breeding or feeding purposes (Bizzarro 2005; Bizzarro et al. 2009). These habitats are relatively sparse, however, along the mountainous Gulf coast of Baja California Sur. The two primary embayments on the Pacific coast of Baja California Sur, Bahía Almejas and Bahía Sebastian Vizcaino, have historically supported active ray fisheries (Villavicencio–Garayzar 1995; Bizzarro 2005; L. Castillo–Géniz, Instituto Nacional de Pesca, Ensenada, Mexico, pers. comm.). Fisheries for rays were documented in Bahía La Paz and Bahía Concepción during this study, but were not extensively sampled. Conversely, large shark fisheries near La Paz were sampled with greater relative frequency, which may have biased overall catch composition estimates. Some large shark species that were previously noted in Baja California Sur shark landings (e.g., narrowtooth shark, *C. brachyurus*; great hammerhead, *S. mokarran*; nurse shark, *Ginglymostoma cirratum*) were not observed during this study (Villavicencio–Garayzar 1996a).

The results of this study have contributed substantially to the information on the artisanal elasmobranch fisheries of Baja California Sur, one of Mexico's most productive states in terms of elasmobranch landings. Although sample size was rather limited, a notable diversity of both sharks and rays was evident in landings, with sharks dominating landings during all seasons. The dominance of early life stages in the landings of the dominant species, *S. lewini*, may be a consequence of a relative absence of large, adult size class. Indeed, the large schools of this species that used to seasonally frequent seamounts in the Gulf of California (Klimley and Nelson 1981; Klimley and Butler 1988) are no longer present (J. Bizzarro pers. obs.). A Gulf–wide management plan for this species should be developed as soon as possible to rebuild overfished populations. In addition, the available biological and fishery information provided here and elsewhere should be compiled and used to develop management plans for at least the primary species landed in Baja California Sur. Using the results of this study as a baseline, it is important that additional research is conducted off BCS to determine any changes in catch rates, species, and size composition that may have occurred since 1998–1999. The historic information presented here should be useful for comparison with this and other contemporary studies.

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